DISTRIBUTION, IDENTIFICATION AND RATE OF SPREAD OF *NOCTUA PRONUBA* (LEPIDOPTERA: NOCTUIDAE) IN THE NORTHEASTERN UNITED STATES[1]

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ABSTRACT : The distribution and spread of *Noctua pronuba* in the eastern United States is reviewed using data collected until the end of the 1994 season. Diagnostic features of the genitalia in both sexes are discussed and illustrated. The rate of spread of *N. pronuba* in the eastern United States averaged approximately 80 miles per year from 1985-1994.

Noctua (= *Triphaena, Rhyacia*) *pronuba* (L.) is a medium-sized moth (wingspan 50-60 mm) with polymorphic pale gray to brown forewings and black-bordered bright yellow hind wings. Because of variability in the forewing pattern, several color forms have been named (see Warren 1914; Wright 1987). The life cycle of *N. pronuba* is well documented, and therefore, good illustrations exist for both the adult (Warren 1914; Alford 1984; Wright 1987; Hill 1987) and immature stages (Döring 1955; Anciloto and Grollo 1970; Neil and Specht 1987; Alford 1984; Aizpurúa 1985; Sannino *et al.* 1988). Information on the systematics and biology of this species can be obtained in Fibiger (1993), Poole (1989), Carter (1984), and Zhang (1994). Although *N. pronuba* has no official common name recognized by the Entomological Society of America, it is often called the large yellow underwing in European literature (Zhang, 1994).

The biology of *N. pronuba* was summarized by Alford (1984), Fibiger (1993), Hill (1987), and Carter (1984). Approximately 1000-2000 eggs are laid from June to October on the leaf undersides or tips of the host plant. Larvae hatch in 10-13 days (Carter 1984) and are polymorphic with green or brown color forms (Neil and Specht 1987). The hosts of *N. pronuba* include grass (*Poa annua* L.), herbaceous and greenhouse plants *(Viola odorata* L., *Primula, Rumex, Polygonum, Atriplex, Myosotis, Taraxacum officinale* Weber, chrysanthemum, *Freesia,* carnations, *Gladiolus),* and crops (tomatoes, potatoes, carrots, beets, cabbage, grapes, various Brassicaceae) (Ancilotto and Grollo 1970; Hoebeke and Wheeler 1983; Zhang, 1994). More rarely, shrubs *(Ribes)* and trees are attacked (Browne 1968; Edland 1978). Although larvae are sometimes abundant, significant damage to agroecosystems is sporadic. Outbreaks have been reported in cole crops, lettuce (Hill 1987), strawberry (Alford 1984) and forest

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nurseries (Carter 1984). Neil and Specht (1987) predicted damage to hayfields because *N. pronuba* is common on grass. Typical of many cutworms in the subfamily Noctuinae (= Agrotinae), feeding occurs near the crown and roots of the host. Larvae overwinter and pupate in the soil during May and June (Carter 1984). Although the flight period can extend through October, adult numbers peak from June through August. This may include a month-long reproductive diapause. Usually one generation occurs annually, but three to four are reported in Israel (Hill 1987). Both sexes of *N. pronuba* are attracted to lights (Wright 1987), sugar baits, and flowers (Fibiger 1993).

The large yellow underwing is native to the Palearctic Region. Recently it was introduced to North America where the first capture was at Halifax, Nova Scotia, in 1979 (Neil 1981). It is now distributed throughout the Atlantic Provinces of Canada west to Ontario (Morton 1994) and the United States, originally at the Maine border (Wright 1987). The purpose of this paper is to update the distribution, diagnosis, and rate of spread of *N. pronuba* in the United States. This will alert regulatory agencies to the presence of a newly introduced potential pest and will provide yet another case study to document pathways used by introduced insects to enter North America.

MATERIALS AND METHODS

We contacted two organizations, the United States Department of Agriculture's (USDA) Cooperative Agricultural Pest Survey (CAPS) program and the Lepidopterists' Society, to solicit collection records for *N. pronuba.* Members of the CAPS program within the northeastern United States were issued color photographs and information on how to distinguish *N. pronuba* from other similar Noctuidae, especially *Noctua comes* (Hübner), to ensure accurate screening of light trap samples for this species (Passoa 1992). The database maintained by the CAPS program, the National Agricultural Pest Information System (NAPIS), does not address pest distributions outside of the United States; thus, records from Canada were not included in this paper. Data not published in peer-reviewed journals (Passoa 1992, Winter 1993) were verified by contacting the collector.

The senior author examined at least one specimen from each state reported in this paper, but many county records sent in by members of the Lepidopterists' Society were accepted on faith. Determination of our study organism was based on a voucher specimen from Maine identified by Dr. R. W. Poole (Systematic Entomology Laboratory, Washington, D. C.) and deposited in the United States National Museum of Natural History.

RESULTS

The following distribution records represent all *N. pronuba* data seen by the authors up to 1995 and include only adults collected mostly at light traps. Unless otherwise indicated by a number in parenthesis, one moth was captured at each locality.

CONNECTICUT: Hartford Co.: 11-VII-1994, C. Maier. **New Haven Co.,** 30-IX-1994, C. Maier. **Tolland Co.:** 21-VIII-1993, J. Trouern-Trend. **MAINE: Cumberland Co.:** Cape Elizabeth, 27-VIII-1990(3), 16-VII-1991, J. Dill. **Knox Co.:** Matinicus Island, VIII-1985, VIII-1986, A. E. Brower; 21-VI-1985, 17-VIII-1985, 1986, 1987, D. Mairs; Vinalhaven, 1987, D. Mairs. **Waldo Co.:** Isleboro, 19-VIII-1988, 8 to 10-IX-1992 (2), W. Winter. **Washington Co.:** Steuben, 23-VII-1987, 19-VII-1988, 11 to 17-VIII-1989 (2), 29-VII-1990, 14 to 28-VIII-1990 (3), 1 to 16-VIII-1991 (4), M. Roberts; Meddybemps, 1986, D. Mairs; Stillwater, 27-VIII-1990, J. Dill (4). **MARYLAND: Anne Arundel Co.:** Annapolis, 13-IX-1993, Maryland Dept. Agr. blacklight survey. **Baltimore Co.:** 17-VIII-1994, Maryland Dept. Agr. blacklight survey. **Dorchester Co.:** Rhodesdale. 19-VI-1994, Maryland Dept. Agr. blacklight survey. **Harford Co.:** 2-VIII-1994, Maryland Dept. Agr. blacklight survey. **Howard Co.:** Glen Elg, 18-VIII-1992, D. Crouch. **Saint Mary's Co.:** 27-VIII-1994, Maryland Dept. Agr. blacklight survey. **Washington Co.:** 17-VIII-1994, Maryland Dept. Agr. blacklight survey. **MASSACHUSETTS: Barnstable Co.:** Truro, 2-VII-1989, 27-VIII-1989, M. Mello; North Truro, 30-VI-1989, M. Mello; Fox Run Circle, 23 to 26-VI-1990, B. Williams (5). **Bristol Co.:** South Dartmouth, 28 to 29-VI-1992 (2). **Middlesex Co.:** Chelmsford, 24 to 26-VIII-1992, G. Holt (2); Holliston, 29-VIII-1991, 20-VII-1992, 11 to 25-VIII-1992 (5), 5 to 7-IX-1992 (3), D. Willis. **Norfolk Co.:** Dedham, 24-VIII-1991, 6-IX-1991, 11-VI-1992, 17 to 20-VII-1992 (2), 3 to 28-VIII-1992 (18), 19-IX-1992, 21 to 26-VI-1993 (4), 29-VIII-1993, 19 to 22-VIII-1993 (9), 23 to 31-VIII-1993 (33), 1-IX-1993, numerous captures from 6 to 10-VI-1994 to 3-X-1994 with a peak of 110 specimens on 25 to 29-VIII, D. Winter. **Plymouth Co.:** Myles Standish State Forest, 27-VIII-1991, 1-VIII-1992, 1-VII-1993, M. Mello. **NEW YORK: Washington Co.:** Cambridge, 25-VII-1992, H. Romack. **Yates Co.:** Bellona, 3 to 10-VIII-1992, J. Knodel (2); 6 to 28-VI-1994, J. Knodel (2). **Ulster Co.:** near Newpalz, 13-VI-1994, S. Adams. **NEW HAMPSHIRE: Coos Co.:** Whitefield, 25-VII-1990, W. Kiel. **Hillsborough Co.:** no other data. **Rockingham Co.:** no other data. **Strafford Co.:** no other data. **VERMONT: Chittenden Co.:** Burlington, 30-VIII-1991; 6-VI to 9-VIII-1992 (9), J. Grehan; Colchester: 16-VIII- 1991, J. Grehan: no collection date, J. Hedbor, South Burlington, 8-IX-1989, collector unknown. **Franklin Co.:** Franklin Bog, 14-VIII-1992, J. Grehan. **Grand Isle Co.:** South Hero, 26-VIII-1992 (4), J. Hedbor; 11-IX-1993, J. Grehan. **Washington Co.:** Waterbury, 25-VII-1992, J. Grehan.

Negative data. A report of *N. pronuba* in Tacoma,Washington,was negative. The specimen examined by the senior author represented *Noctua comes.*

The NAPIS database contained the following negative data from blacklight traps: Minnesota Department of Agriculture surveyed 15 counties but did not capture any *N. pronuba* in 1994; Maryland Department of Agriculture reported one positive and 21 negative counties for *N. pronuba* in 1993; by 1994, 23 counties were surveyed in Maryland but only two were positive; and the New York Agricultural Experiment Station (Geneva) did not find *N. pronuba* in either Clinton, Essex or Ontario counties in 1994.

DIAGNOSIS

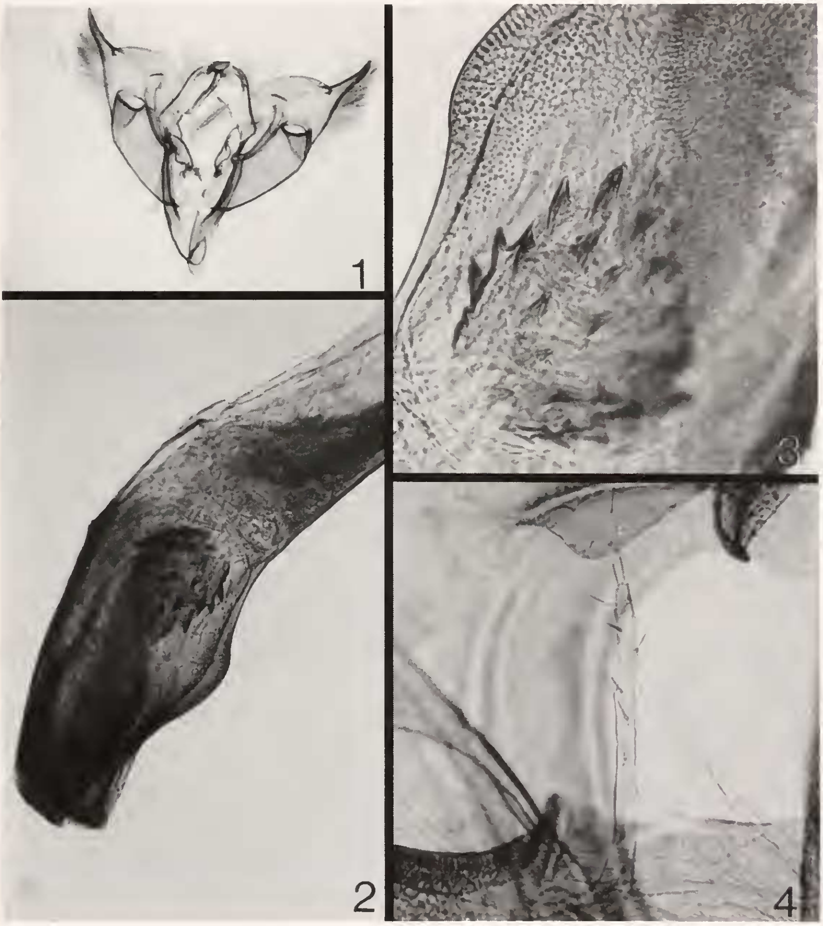
Although *N. pronuba is* frequently identified by the characteristic yellow hindwing with a black border, it may sometimes be confused with the smaller *N. comes* (see Results). The presence of a black hindwing discal dot usually, but not always, will distinguish *N. comes. Noctua pronuba* lacks the dot in all color forms except one (Fibiger 1993). The male genitalia of both species are very different. According to Neil (1984), the valve of *N. comes* is long, thin, and has a knoblike process. There is no knoblike process in *N. pronuba,* and the valve shape is much wider (Fig. 1). Pierce (1909) illustrated the male genitalia of *N. pronuba,* except for the aedeagus. The cornuti of *N. comes* consist of two series of spines that differ in size (Neil 1984), in contrast to *N. pronuba,* where the cornuti are clumped in a cluster of approximately equal size (Figs. 2, 3). Unlike *N. comes* (Neil 1984), an ampulla (a thin rodlike structure) is present on the valve of *N. pronuba* (Fig. 4).

Female genitalia can also distinguish *N. comes* from *N. pronuba.* The most obvious difference is the lack of sclerotized bands in the corpus bursae of *N. comes* (Neil 1984); these are present in *N. pronuba* (Figs. 5, 6, 7). Pierce (1952) illustrated the female genitalia of *N. pronuba* with a v-shaped genital plate. Actually, the area anterior to the ostium has a medial indentation (Fig. 8). The texture of the corpus bursae of *N. comes* has only a small area of wrinkled cuticle (Neil 1984) whereas this texture is widespread on the same structure in *N. pronuba* (Fig. 9).

DISCUSSION

One obvious need of regulatory entomology is an ability to predict the geographical range of introduced insects. Two main methods have emerged. The Office of Technology Assessment Report (1993:86-87) graphed the cumulative number of states where a target organism was collected during a given year. For *N. pronuba,* based on United States data, a similar graph is shown in Figure 11. Initially, the range remained constant during 1985-1988, and *N. pronuba* was known only from Maine. From 1989-1993, when the CAPS survey was most active, the rate of spread (slope) was 4 (7-3) states in 4 years (1993-1989), or about one state per year. This pattern is similar to other introduced insects (*e.g.,* gypsy moth, *Lymantria dispar* L.). From 1870-1900, there was little spread and only a few states were infested (Office of Technology Assessment Report 1993: 87). The highest rate of gypsy moth movement was from 1970-1990, almost 100 years after the initial introduction, where the known infestation jumped from 10 to 20 states in 20 years, or about .5 states/year (Office of Technology Assessment Report 1993: 87). This is similar in magnitude to the figure for *N. pronuba* given above.

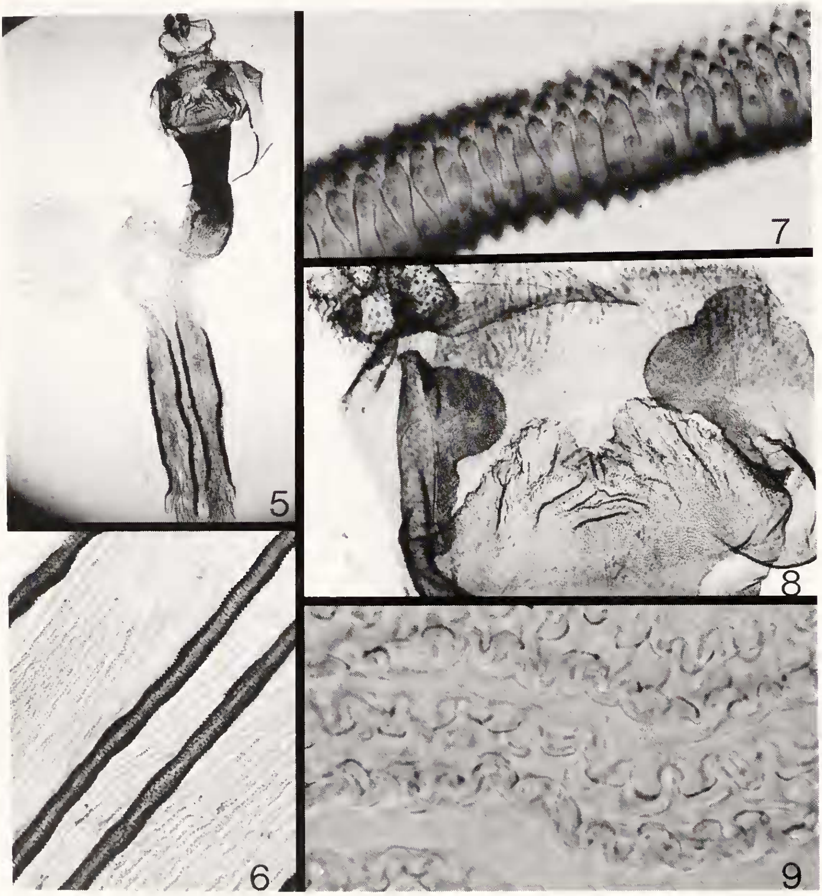
Another method used by Liebhold *et al.* (1995), Neron and LeGault (1992), and Ferguson (in press) documents the rate of spread of an introduced pest in terms of distance traveled/year. These figures were calculated by dividing the distance of the farthest expansion by the time a target organism used to reach that point. For *N. pronuba* in eastern North America, this figure is approximately 800 miles/10 years, or 80 miles/year, which compares to 55 km (= 35 miles)/year calculated by Neron and LeGault (1992) for *N. pronuba* in Canada.



Figures 1-4. Male genitalia of *Noctua pronuba*. 1, ventral view with valves spread (10 x). 2, aedeagus, lateral view (40x). 3, cornuti of aedeagus (100x). 4, ampulla (160x).

Several factors have probably contributed to the spread of the large yellow underwing in North America including wind (Specht and Mairs 1986), migratory habits of the adults, and wide host range of the larvae (Neron and LeGault 1992).

A comparison of the gypsy moth with *N. pronuba* is especially interesting in light of differences between the two species. Although the spread of the gypsy moth may have been assisted by humans (Liebhold *et al.* 1995), the maximum rate of spread for this species is only 13 miles/year(Liebhold *et al.* 1995). Be-



Figures 5-9. Female genitalia of *Noctua pronuba*. 5, ventral view (10 x). 6, sclerotized bands on corpus bursae (100x). 7, enlargement of sclerotized band (400x). 8, ostium bursae, ventral view (40x). 9, texture of corpus bursae between sclerotized bands (400x).

cause *N. pronuba* lays eggs in houses (Carter 1984), but not on vehicles, humans probably will not play a role in the movement of this species. Adults of *N. pronuba* are migratory (Fibiger 1993); females of the European strain of the gypsy moth do not fly (Schaefer 1988). Efforts were made to control the spread of the gypsy moth (Office of Technology Assessment Report 1993); no control action was taken for *N. pronuba* by the USDA Animal and Plant Health Inspection Service. Perhaps 13 to 100 miles are opposite ends of an extreme where an extensive quarantine leads to a slow spread in the case of the gypsy moth and uncontrolled migration of *N. pronuba* leads to rapid colonization.

Clearly, the two methods have many problems and caveats, perhaps this is the reason why published reports rarely try to present such data. In the case of all distributional studies, there is an "entomologist-area effect", which implies

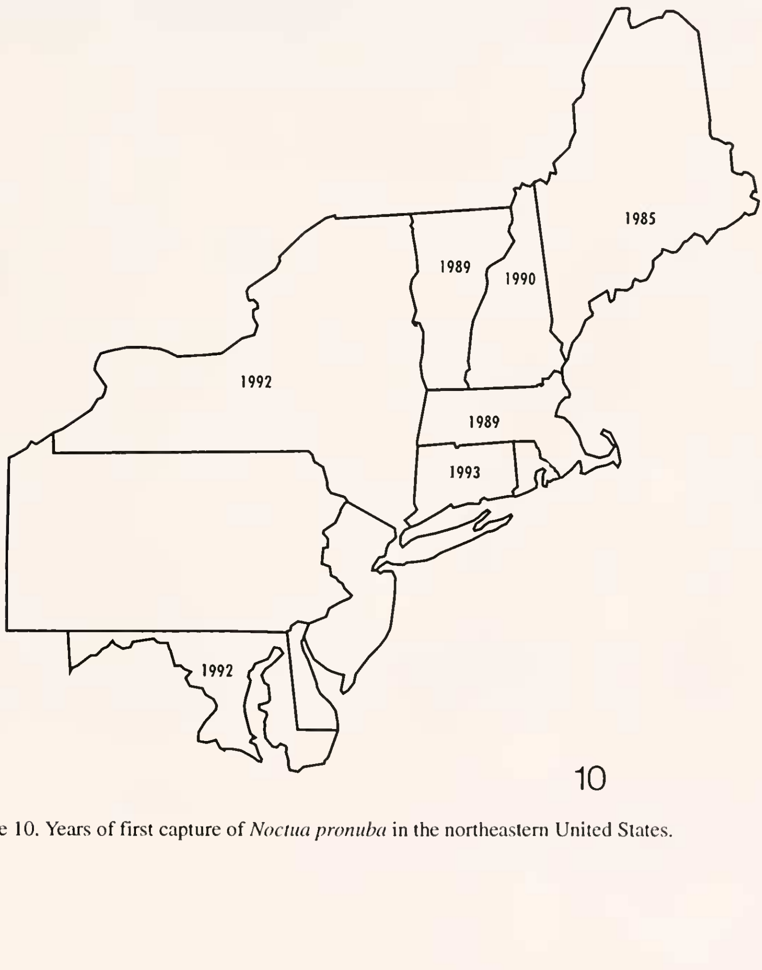


Figure 10. Years of first capture of *Noctua pronuba* in the northeastern United States.

that records can only occur where researchers are actively collecting data. A figure for the number of states colonized/year is misleading because states vary so much in size. Distance measures are more accurate but mean less from a political standpoint because most quarantine decisions are made on a county, state or regional basis. If an insect crosses the county line, the whole county can be quarantined, which "extends" the distribution of the pest far beyond where it actually colonized. However, data on introduced insects are most reliable when the insect is easily recognized and the sampling area is well-collected. This is the case for *N. pronuba* in the eastern United States, where most states contain lepidopterists capable of recognizing the large yellow underwing, and many individuals operate a light trap on a regular basis.

In summary, quantitative measures of introduced insect distributions need to be developed and reported, especially because the rate of spread is highly variable between species. If we can not trust our positive introduced insect records because of a lack of regionwide negative data, this would seem to justify a need for the continued support of domestic surveys such as the CAPS program.

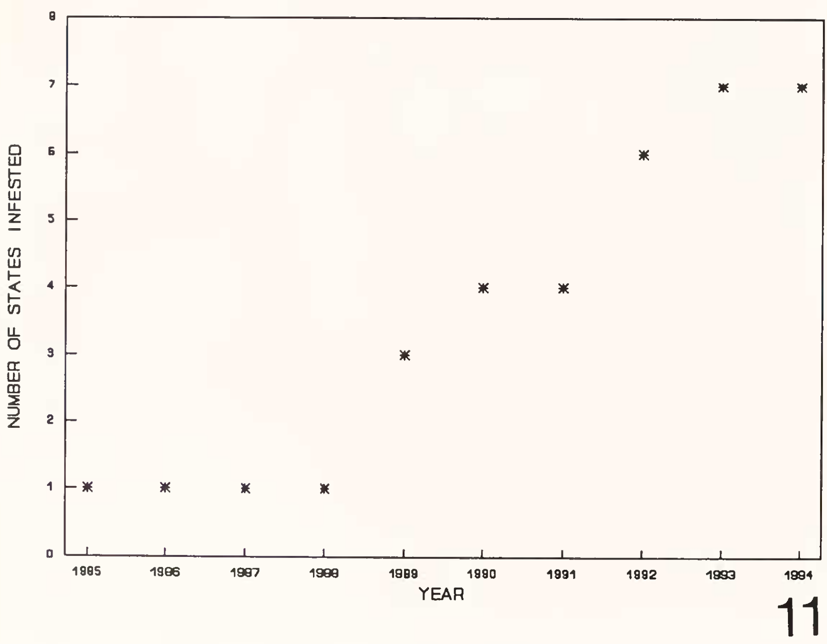


Figure 11. Rate of spread of *Noctua pronuba* by cumulative number of states infested in the eastern United States per year.

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LITERATURE CITED

Aizpurúa C. G. de. 1985. Biología y morphología de las orugas. Tomo I. Noctuidae-Dilobidae. Boletin de Sanidad Vegetal (Fuera de serie) numero 5. Ministerio de Agricultura, Pesca y Alimentación. Madrid, Spain. 227 p.

Alford, D. V. 1984. A colour atlas of fruit pests, their recognition, biology and control. Sheridan House, Inc. London, England. 320 p.

Anciloto, A. and G. Grollo. 1970. Nel mundo delle farfalle i bruchi. A. Mondadori Ed. Milan, Italy. 201 p.

Browne, F. G. 1968. Pests and diseases of forest plantation trees. Claredon Press. Oxford, England. 1330p.

Carter, D. 1984. Pest Lepidoptera of Europe. Series Entomologica, volume 31. Junk Publishers. Netherlands. 430 p.

Döring, E. 1955. Zur Morphologie der Schmetterlingseier. Akademie-Verlag. Berlin, Germany. 154 p.

Edland, T. 1978. Lepidopterous species recorded on fruit crops in Norway. Norwegian Jour. Entomol. 25: 103-105.

Ferguson, D. (in press). Range expansion rates for *Lymantria dispar* (L.) and other introduced Lepidoptera in eastern North America.

Fibiger, M. 1993. Noctuidae Europaeae. Volume 2. Noctuinae II. Entomological Press. Sorö. Denmark. 230 p.

Hill, D. 1987. Agricultural insect pests of temperate regions and their control. Cambridge University Press. Hazell Watson and Viney, Ltd., Great Britain. 659 p.

Hoebeke, E. R. and A. G. Wheeler, Jr. 1983. Exotic insects reported new to northeastern United States and eastern Canada since 1970. Jour. New York Entomol. Soc. 91: 193-222.

Liebhold, A. M., J. A. Halverson and G. A. Elmes. 1995. Gypsy moth invasion: a quantitative analysis. Jour. Biogeography 19: 513-520.

Morton, J. K. 1994. The large yellow underwing, *Noctua pronuba* Linn. (Lepidoptera: Noctuidae), in Ontario. Canadian Field Naturalist 108(1): 83.

Neil, K. A. 1981. The occurence of *Noctua pronuba* (Noctuidae) in Nova Scotia: A new North American record. Jour. Lepidopterists' Soc. 35:248.

Neil, K. A. 1984. *Noctua comes,* a noctuid new to North America (Lepidoptera: Noctuidae: Noctuinae). Canadian Entomol. 116: 479-480.

Neil, K. A. and H. B. Specht. 1987. Sixth-instar-larvae of *Noctua pronuba* (L.) (Lepidoptera: Noctuidae). Canadian Entomol. 119 (3): 209-214.

Neron, D. and P. LeGault. 1992. Extension d'aire de *Noctua pronuba* Linné (Lepidoptera: Noctuidae) des maritimes jusqu'à Montréal. Fabreries 17(2): 50-54.

Office of Technology Assessment: 1993. Harmful non-indigenous species in the United States. Washington, D.C. OTA-F-565. 391 p.

Passoa, S. 1992. 1991 Annual Report with Appendices. United States Department of Agriculture/ Animal and Plant Health Inspection Service/ Plant Protection and Quarantine. Reynoldsburg, Ohio. 90 p.

Pierce, F. N. 1909. The genitalia of the group Noctuidae of the Lepidoptera of the British Isles. An account of the morphology of the male clasping organs. Liverpool, England. 88 p.

Pierce, F. N. 1952. The genitalia of the group Noctuidae of the Lepidoptera of the British Isles. An account of the female reproduction organs. Reprinted by E. W. Classey. London, England. 64 p.

Poole, R. W. 1989. Lepidoptorum Catalogus (new series). Noctuidae. Fascicle 118. E. J. Brill. Ft. Lauderdale, Florida. 1314 p.

Sannino, L., A. Balbiani and B. Espinosa. 1988. Studio morphologico comparativo sugli stadi preimmaginali dei lepidotteri che attaccano il tabacco in Italia. I. Crisalidi e bozzoli. Annali Dell Instituto Sperimentale Per Il Tabacco 14: 163-194.

Schaefer, P. 1988. Diversity in form, function, behavior and ecology: an overview of the Lymantriidae (Lepidoptera) of the world. Pages 1-19. *In* W. E. Wallner and K. A. McManus (eds.). Lymantriidae: a comparison of features of New and Old World tussock moths. USDA/Forest Service General Technical Report NE 123.

Specht, H. and D. Mairs. 1986. Weather conditions leading to the introduction of the large yellow underwing moth, *Noctua pronuba* (L.) into Maine. Proceedings of the Acadian Entomol. Soc. 46: 19.

Warren, W. 1914. Noctuidae. *In* Seitz, A. The Macrolepidoptera of the World. A. Kernen. Stugart. Germany.

Winter, D. 1993. Season Summary. *Noctua pronuba. In* McKown, S. (ed.). News of the Lepidopterists, Soc. 46(2): 47.

Wright, B. 1987. The European yellow underwing, *Noctua pronuba* L. (Lepidoptera: Noctuidae) in the Atlantic Provinces (Canada) and the state of Maine (USA). Canadian Entomol. 119: 993-997.

Zhang, B. C. 1994. Index of Economically Important Lepidoptera. CAB International University Press. Cambridge, England. 599 p.